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so as to make artificial reservoirs; then encouraging a judicious vegetation to check evaporation; and finally trusting to the stamping of the feet of sheep to harden by puddling the surface of the land in the neighbourhood of the newly-formed pool.*

X.—*On the Climate of the North Pole, and on Circumpolar Exploration.* By W. E. HICKSON, Esq.

Read, April 10, 1865.

A REVIVAL of interest in Arctic discovery has led me to ask attention to some astronomical considerations, relating to the probable climate of the North Pole, and, connected with them, to other data, bearing upon the question of the direction that should be given to any new expedition that may be organised for the Polar Seas.

It has always been popularly supposed that the immediate areas of the Poles must be the coldest regions of the globe, because the farthest points from the equator. Hence the argument that the higher the latitude the greater must be the difficulties and dangers of navigation; a belief encouraged by a work of some reputation, the 'Révolutions de la Mer' of M. Adhémar; who, seeking to account mathematically for the shifting, in times past, of the bed of the ocean, imagined ice to accumulate at the Poles, continuously but unequally, in such immense masses as to disturb the earth's centre of gravity. It was, perhaps, under the influence of this extreme hypothesis that a writer in one of our best weekly periodicals was induced recently to remark, by way of objection to Capt. Osborn's proposal, that "the hardships and perils of Arctic expeditions have only yet been skirted," and that "new horrors await new exploration."

Quite an opposite opinion, however, had begun to prevail among meteorologists on the publication, in 1817, of the Isothermal System of Alexander von Humboldt, which showed that distance from the equator is no rule for cold, as the equator is not a parallel of maximum heat. The line of maximum heat crosses the Greenwich meridian, in Africa, fifteen degrees north of the equator, and rises, to the eastward, five degrees higher; running along the southern edge of the Desert of Sahara.

In 1821 Sir David Brewster pointed out, in a paper on the mean temperature of the globe, the probability of the thermometer being found to range ten degrees higher at the Pole than in some outer parts of the Arctic circle. No new facts have since been

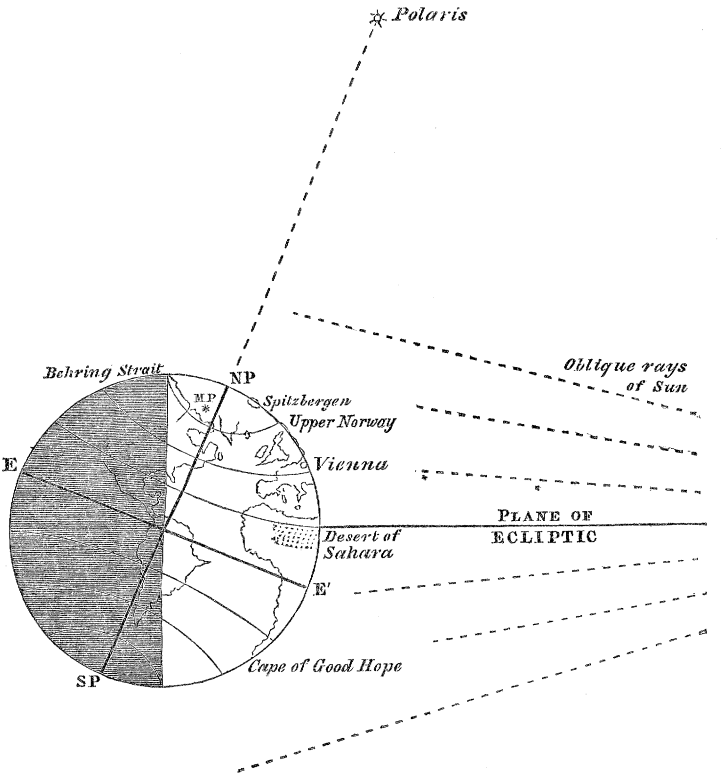
* For this last suggestion I am indebted to Mr. Francis Galton.

discovered to invalidate this conclusion; many, on the contrary, have come to light tending to confirm it;* but much misapprehension still exists on the subject, which can only be dispelled by explaining the Pole's solar position.

The temperature of all places on the earth's *surface* (whatever may be the state of its centre) are primarily governed by their solar aspects; that is to say, by their proximity to or distance from the sun, and the relative directness or obliquity of the solar rays. Now, at no time of the year is the Pole either the nearest point to the sun or the farthest from it. Neither in summer nor winter are the solar rays that reach the Pole at noon either so direct or so oblique as at other places; the reason being, that the Pole, instead of being at right angles with the plane of its orbit (called the ecliptic) is inclined to it, from the perpendicular, twenty-three and a half degrees; the parallelism of which inclination is not affected by the earth's rotatory or diurnal motion. These are elementary principles, the application of which should be easy to every one who has studied at school "the use of the globes;" but from their importance to the interests of Arctic navigation I must ask permission to make them clear to general readers by a diagram.

The diagram represents the midsummer position of the earth, with different places upon it, looking towards the sun at noon, on or near the same meridian as Vienna; which is in longitude 1 h. 5 m. 31 s. E., and in latitude 48° 12′ 35″ north; that is, north of the equator; but it will be understood from the diagram, that, in estimating solar influence, we have to count our latitude as we reckon that of the stars, from the plane of the ecliptic, and not from the equator. At midsummer noon, Behring Strait is situated 90° from the plane of the ecliptic; the North Pole 66½°; Spitzbergen (on the polar side) 56°; Upper Norway 43°; and Vienna 25° of the same plane. We should expect, then, to find, what in fact we do find, a lower temperature in Behring Strait, about the 21st of June, than in Norway, on the same parallel; and the difference would be greater than it is but for the earth's diurnal motion. Our diagram shows *noon* positions only. At midnight, Behring Strait and Upper Norway change places; E and E′ on the equator doing the same. The climate, or mean temperature of all places on the face of the globe, is governed by this diurnal change of their ecliptic or celestial latitude; involving, outside the Arctic circle, an alternation of forty-seven degrees, and consequently a maximum and minimum of heat every twenty-four hours. The Poles are an exception.

* Dr. Kane, at first shaken upon this theory by the extreme cold of Rensselaer Harbour (nearly at foot of the Great Humboldt glacier, the largest in the world, in lat. 78° 37′ north), found, 200 miles farther *north*, a warmer climate, an iceless ocean, or what appeared such, with "the rocks and shore crowded with sea-swallows; birds whose habits require open water."



Their day and night, their summer and winter, are dependent solely upon the earth's *orbital* motion. Whatever, therefore, the climate of the Poles, their mean temperature from day to day must be more *equable* than that of England, or any other country.*

In winter, the earth having gone round to the opposite side of the sun, the relations of light and darkness, as shown by the open and shaded parts of our diagram, are reversed; but not even in the depth of winter is the North Pole so far from the sun as are many other parts of the globe at midnight.

The fact, however, that the sun is longer absent from the Pole in winter than from other parts of the Arctic circle raises the question of whether the Polar winter, towards spring, may not be colder; but if so, the Polar autumn must be in a corresponding degree

* An important fact; for, although the *mean* of two temperatures—say 50° and 20°—is 35°, it is not the same thing as a *uniform* temperature of 35°. A plant that would live at 35°, would die at 20°; and the human constitution is most tried by sudden changes.

warmer, from the longer presence of the sun at the Pole when its summer has once commenced. At the Pole the sun never sinks below the horizon during six months in the year, and never rises above it during another six months; while in the outer parts of the Arctic circle, when not near the solstices, there is always more or less alternation of day and night within the twenty-four hours.

And this leads me to mark another peculiarity of a Polar climate, important to voyagers, that summer at the Pole begins and ends nearly three months earlier than in the lower latitudes of the same regions; the reason being, that, a few days only after the vernal equinox, the sun at the Pole remains constantly above the horizon, and, soon after the autumnal equinox, is as constantly below it; before, even at Spitzbergen, the days and nights have begun sensibly to lengthen and shorten, and while they, there, yet remain of nearly equal length.

We have also to bear in mind that the night of the Pole, which begins about the 30th of September, and ends about the 30th of March, is rather a prolonged evening than a night, in the sense of absolute darkness. There is always twilight when the sun is not more than eighteen degrees below the horizon; and its depression, at the Pole, is less, four months out of the six; while the sun's extreme depression on the 21st December is but twenty-three. Through a great part, also, of the Polar night there is nearly perpetual moonlight, the moon when at full never setting; and as the Arctic moon is often surrounded with halos of beautiful colours, while the stars are of great brilliancy, and the skies are irradiated besides with the flashing lights of the aurora borealis, the night of the Pole may not only be endurable but even more enjoyable than our short days at the same season, obscured by winter fogs.*

Related to these facts are the phenomena of the earth's magnetic currents.

As far back as 1683 it was announced by Newton's friend and coadjutor, Dr. Halley, that the variations of the needle indicated lines converging upon four magnetic poles; two in the northern, and two in the southern hemisphere. This statement, long neglected, was examined and confirmed at the beginning of the present century, by Professor Hansteen, of Christiana, and is now generally held to have been verified, and in part demonstrated, by the discovery, in 1831, by Sir John and Sir James Ross, of the exact site of one magnetic pole (marked in our diagram with an asterisk) in Felix Boothia, lat. 70° N. The progress of science having also established the correlation, or mutual dependence of heat and magnet-

* Dr. Kane says, "The intense beauty of the Arctic firmament can hardly be imagined; it looked close above our heads, with its stars magnified in glory; and the very planets twinkling so much as to baffle the observations of our astronomer."

ism, it may now be assumed that the magnetic pole of Boothia Felix stands on the parallel where, *at sea-level*, the influence of the sun's rays is at its minimum.*

The probability, therefore, of finding greater cold at the North Pole than elsewhere seems confined to the solitary chance of the Pole being covered by a lofty mountain-range, the elevation of which would render it a region of glaciers. Against this supposition we have, first, the spheroidal theory of the earth being flattened at the Poles, and next the fact, that on all sides on which the North Pole has been approached there have been found seas. In July, 1827, Sir Edward Parry stood upon floating ice within 435 miles of the Pole; and the ice drifting him southward, proved that there was not only sea, but open sea before him. On the 11th of August, the ice breaking up under him, he took to his boats, in latitude 81° 34′, fifty miles from the nearest land,—Ross's Islet and Little Table Island, on the north-east side of Spitzbergen; before reaching which the thermometer rose to 41° Fahr., and not a trace of ice was to be seen in any direction. Could he, then, have jumped on board a screw-steamer, it is more probable than not that by returning northward he might have reached the Pole in three days!

The application of steam-power to navigation was then in its infancy; but strange it is, that, with the giant means now at our command, the value of the lesson then taught should still be overlooked. Its importance, even without steam, was long ago pointed out by General Sabine. Five-and-twenty years have elapsed since a paper of mine supporting his views of the Spitzbergen route appeared in the 'Westminster Review.'† In 1844 the Russian Admiral, Von Wrangell, in a letter to General Sabine, repeated his own conviction of open water at the Pole, and expressed his belief that it would be possible to follow and reach it by way of Spitzbergen. Subsequently, Dr. Petermann has frequently, and with great ability, brought the subject forward; but to this day no new expedition has left our shores in the direction of Parry's fourth voyage; the most likely one of all to lead us direct to our object!

Yet we must surely have now acquired sufficient experience to form a shrewd *guess* at least of the cause of our repeated failures.

It is not the ice at the Pole, but the ice drifting away from it, or circulating round it, in the Polar summer, and blocking up all approaches by narrow seas, that forms the great impediment to Arctic navigation. The problem is how to avoid being caught

* During a three weeks' sledge-expedition along this coast, ending March 14, 1849, Sir Leopold M'Clintock found the mean temperature 30° below zero of Fahr., or 62° below the freezing-point of water.

† Vol. xxxiv. for Oct. 1840, p. 523.

in this drifting ice of the surface currents, and get into the open water beyond. We have been attempting, for two hundred years, not to solve this problem, but to force a passage through an ice blockade to the north-west, along the coast of America, or to the north-east, along the coast of Asia, with the certainty, acquired beforehand, that in the whole stretch of those immense continents there is no opening by which the ice can escape. The voyager caught in the pack, along either of those coasts, must wait till it melts; and when the mass is too great to melt, in a northerly latitude, must perish, as the unfortunate crews of the *Erebus* and *Terror* perished in 1848.

There are but two outlets for the ice of the Arctic circle—Davis's Strait and the Greenland Seas. Behring Strait may be called a third outlet, but there the current sets inward. Davis's Strait is a wide channel, but not one-fifth of the breadth of the Greenland Seas, in the same parallel. It conducts due north, through Smith's Sound, to a strait 200 miles in length, which Dr. Kane, in the three summers of 1853, 1854, and 1855, and Dr. Hayes, in 1861, found choked up with hummocks and ice-bergs, and which Captain Osborn proposes we should again explore.* The direction of this frozen strait, ending in Kennedy's Channel, is all that can be desired; but, with the almost certainty of its not being found open, although with open water beyond, to reach it we have to creep along a cold and dangerous meridian, that of the western or Baffin's Bay side of Greenland, the glaciers of which, not to be crossed by land, are perpetually projecting ice-bergs into the sea. The opposite coast of Smith's Sound may, however, it is hoped, offer facilities for reaching the Pole by sledge-travelling.

Now, with an Admiralty chart before us, or with Mr. Wyld's little map of the Arctic regions in our hands (a third edition of which has been opportunely published), let us look at the position of Spitzbergen. It is in an ocean of which we were told in 1827, "that a ship might have sailed before the middle of August almost without touching a piece of ice, as high as latitude 82° N.;" † and where, if, notwithstanding, our progress northward, in a stout vessel, be baffled by ice, it is by ice that, having a perfectly free passage (at the proper season), merely drifts us back again, homeward, and no harm done.

A free passage for ice, by an outward current, carrying away

* Partly in the belief that "Dr. Kane departed from an Arctic canon by keeping on the eastern or lee shore, instead of the western or weather shore;" but in Dr. Kane's official report to the Secretary of the United States Navy, he states, "My first design on entering the pack (Aug. 1853) was to force a passage to the north; but, after reaching latitude 78° 45′ north, we found the ice hugging the American shore, and extending in a drifting mass completely across the channel."

† Parry's fourth voyage, last paragraph.

cold with it, implies, also, a free passage for the warm equatorial counter-current of the Gulf-stream; and thus, from a double cause, we get, along the coasts of Norway and Spitzbergen, a much higher mean temperature than on any of the meridians, in the same parallels of latitude, that cross the continents of North America and Asia. In Upper Norway, fine forest timber is growing in latitude 70° N.; while the ice blockaded coasts of Hudson's Bay (on the meridian of the Boothia Magnetic Pole) are barren of trees and shrubs, as low as 55° N. In Spitzbergen rain falls at Christmas; wild reindeer find subsistence throughout the year on alpine plants and mosses; and there the crews of whalers have repeatedly wintered, time out of mind. The great advantage, however, of this route is, that, for an attempt by navigation, there need be no wintering, except in cases of accident; for Spitzbergen, the south point of which is accessible all the year round, may be reached by steam, from London, in a fortnight, in the month of July; and, with an open sea, a voyage to the Pole and back would only be an affair of six weeks for a Cunard steamer. The distance of the Pole from Greenwich, let it be remembered, is a fourth less than that of New York.

Would it not be well, then, some day when Parliament is sitting, for the question to be asked in the House, or, otherwise, for a deputation to wait on the First Lord of the Admiralty, to inquire whether one or two steamers of our magnificent screw fleet, kept in readiness for war, and cruising occasionally as far as Malta and back to prevent their machinery rusting, might not, with advantage to the service, make, annually, a summer trip to the Greenland seas; if with no other result than that of familiarising our younger officers with navigation in high latitudes. Should the answer be in the affirmative, we might then, in the interests of science, venture to request an annual report of the direction of all currents, new lines of coast, and fixed and floating masses of ice, found in the neighbourhood of Spitzbergen; and for leave to be given the officers in command to go ahead, should they meet with an open channel.

For such preliminary expeditions, which would soon settle the question of the extent of the open water found by Sir Edward Parry, and with which might be combined a survey of the north-east coast of Greenland, no addition would have to be made to the navy estimates, beyond that which might be required for establishing at some point of Spitzbergen a depôt for coals and fresh provisions; and the vessels we send out need not leave port before the heats of summer render a northern breeze pleasant. With steam-power we have to economise coals, and nothing is to be gained but hard knocks (as serious off Spitzbergen as elsewhere) by buffeting with the ice-floes of spring. We should allow

(which has not generally been done) the sun fully four months from the vernal equinox for its work of ice dispersion in Polar seas. August is the month for maritime exploration,* and, with a week or ten days borrowed from September, would give ample time for all that should be attempted on a first voyage. Early in October our Arctic steamers should be again in the Thames, bringing with them, let us hope (if not this year, the next, or the next following), the glorious news that the dream of astronomers may yet be realised, and that there exists no practical obstacle to the erection of an observatory under *Polaris;* upon which depends the solution of many scientific problems of the highest interest, and the final corrections of all our latitudes and longitudes.

It may be useful to add a few words upon the scientific objects to be attained by reaching the Pole, as contradistinguished from those of Arctic exploration generally.

The first object is that of obtaining reliable data for a knowledge of the exact figure of the earth; the importance of which to navigation is not well apprehended by the public at large, and may, therefore, here call for some brief explanation.

Astronomy enables us to determine, approximatively, the relative positions of different places on the face of the earth, but not their precise distances apart, in feet or yards, nor, when the distances are considerable, even in miles. An English mile is a definite length of 5280 feet, but the geographical miles and geographical degrees of our charts are variable terms. A geographical mile means the sixtieth part of a degree, and a degree is the three hundred and sixtieth part of the earth's circumference; but, owing to differences of the earth's curvature, a degree, which between London and Birmingham measures 69 English miles, measures $69\frac{1}{2}$ English miles (north and south) on the Arctic circle, and but $68\frac{3}{4}$ English miles (north and south) on the equator. A geographical mile is 6080 feet at Blackwall (whence that number of feet is taken for the length of the *log* mile of ship measurement), but is only 6040 feet, measuring north or south from the equator, and is 6116 feet, north or south, from the Arctic circle.

Hence a fruitful source of shipwrecks; for, in thick weather, when observations of the heavenly bodies cannot be taken (which often happens for weeks together), a mariner must work his ship

* *Time* is an essential element in Arctic exploration. Parry left with his sledges late in July, when, as the ice was beginning to break up, steamers, or even sailing vessels, would have been more useful. Spitzbergen would be an excellent starting-point for a sledge expedition to complete, on the north-east coast of Greenland, the American discoveries; but, for ice-travelling, it should leave in March.

by log and compass; and then, to the ordinary dangers of navigation, is added the risk arising from his ignorance of the exact number of log miles, or *knots*, to be passed over on the course he is steering before reaching a given point. With the utmost care of his "dead reckoning," and from no fault of his own, he may find himself some miles nearer a dangerous reef of rocks than the position in which he would have placed his ship had he known, with precision, the length of his geographical degrees.

Astronomers and geodetic surveyors are now quite at issue as to the rules that should be laid down for the guidance of mariners on this subject; especially since the discovery that deflections of the plumb-line and spirit-level from local attraction (not generally allowed for in taking latitudes and longitudes) are more general, and of greater extent, than had been suspected. General T. F. de Schubert, a high authority, holds the earth to be "an ellipsoid with three unequal axes," * instead of a spheroid compressed $\frac{1}{300}$ part at the Poles, as supposed by Newton. M. O. Struve, the astronomer at Pultowa, writes that,† from the effects of local attraction, no zenith observations are to be relied upon in the neighbourhood of Moscow; and M. de Gumbach, after comparing the results of all the geodetic surveys hitherto completed, has revived the doctrine of Newton's contemporary, the first Cassini, that the equatorial axis of the globe is shorter than the Polar, and that the earth is not depressed but elongated at the Poles.‡

The data most required for determining this problem are measured lengths of degrees from and round one or other of the Poles, and measured lengths of degrees, east and west, along the equator; where, strange to say, as remarked by M. Le Verrier,§ only meridian surveys have yet been undertaken, and where M. de Gumbach asserts the true circumference of the globe will be found less by 167 miles than the received circumference, computed by theory.

The question of the exact figure of the earth involves another of equal importance to navigation, belonging to the compass—that of the exact direction of the four cardinal points. A mariner is told that the needle is subject to a periodic cycle of variations, east and west of the true north. But where is the true north? A point about 1° 36′ from *Polaris* is called the true north of the heavens,—the Celestial Pole. But where, precisely, is its representative on earth,—the Terrestrial Pole? Can any astronomer

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* Astronomical Memoirs for 1861.

† Communication to the Royal Astronomical Society, at the Meeting of 10th of April, 1863.

‡ 'True Figure and Dimensions of the Earth,' by J. Van Gumbach. Hardwicke.

§ Academy of Sciences, Sept. 1, 1862.

give us its bearings and distance from some known headland of the Arctic seas within a limit of error of five or ten miles? No; for the exact latitudes and longitudes of most places visited in the Arctic regions is doubtful. One of the nearest to the Pole, Cape Constitution, is placed by American hydrographers in latitude 81° 22′ N., and by Mr. Arrowsmith in 80° 56′ N.; a difference of 28 miles! This uncertainty arises from the almost horizontal path of the heavenly bodies, as seen in high latitudes; which interferes with the simpler methods of astronomical observation. At the Pole, for example, the sun at Midsummer sails round and round the horizon for nearly a week together at a uniform altitude of 23° 28′, plus refraction. It has no culmination. The hour of noon might, then, easily be mistaken for that of midnight, and is only to be determined approximately, by chronometers.

Hence, and for other reasons, the discovery of some island or continent in which the Pole may be situated (and let us hope it is not in the dominions of Neptune), although no mean achievement, will not probably be found so difficult an undertaking as the *identification* of the Pole, when found, to the satisfaction of science. Our first explorers may be able to assure us that they have sailed round the Pole, or landed and camped somewhere near it, but this is a very different thing from marking out the exact spot which constitutes the most northerly point of the globe. A geodetic surveyor, having to adopt it as his measuring point for all areas of meridian, will require to have the Pole so defined by astronomers that he shall be enabled to trace out, under their direction, as the terrestrial representative of the celestial Pole, a circular area of 100 feet radius, the centre of which shall be latitude 90° N., and the circumference of which shall be one second less, or 89° 59′ 59″ N. Before this can be done, a long series of observations, from the approximate area first fixed upon, and spread over a year at least, must be completed and compared; especially for the two solstices and the two equinoxes; the reason being that from many different causes, some of them not understood, the *apparent* positions of the heavenly bodies always vary somewhat from their calculated positions,* and that the full extent and *mean* of such variations have to be allowed for, in all cases of latitudes and longitudes, whenever the precision of a second is aimed at.

Besides the orbital and diurnal motions, observations at the Pole would be affected by—1. *Precession;* a motion of the earth, and perhaps of the whole solar system,† round the Pole of the Ecliptic,

* The Greenwich Observations for 1859 show a range of apparent errors in the vertical diameters of the sun, computed for the Nautical Almanac, of nearly 9″; that is, from +4·61 on March 2 to −4·12 on the 24th May.

† From changes in the apparent position of the fixed stars Dr. Maskelyne and Sir William Herschel were led to conclude that the sun moved in an orbit of its

at the rate of 50·″2549 annually; complete in 26,868 years; changing, therefore, continuously the apparent longitude of the stars; but held by most astronomers (some doubting) to be so perfectly horizontal as not to affect their latitude. 2. By *Nutation*, an oscillatory movement of two kinds, horizontal and vertical; the horizontal involving a correction for longitudes, and the vertical for latitudes,* the extreme range of which is 18″ in a cycle of nearly 19 years; affecting to that extent, for the same period, the obliquity of the ecliptic. 3. By *a displacement of the plane of the ecliptic* (*i. e.* a change of angle in the direction of the earth's orbital path), affecting its obliquity more permanently and continuously; and which has diminished the latitude of certain southern stars, and augmented that of corresponding northern upwards of 20′ since the days of Hipparchus and Ptolemy.† 4. By *the motion of the earth's apsides* (or changes, laterally, of solar distance); planetary disturbances varying the eccentricity of the earth's orbit. And 5. Possibly, by what Newton called *an evagation of the Poles;* that shifting of the earth's axial line of rotation which might arise from any unequal enlargement or diminution of the earth's mass, by foreign influences;‡ in which case the spot we may now fix upon as the Pole would not be the Pole of some future century.

These considerations make it very desirable that if the Pole be found accessible, and its climate not too unfavourable, arrangements should be made for establishing there, for at least some years, a permanent station;§ that the work of Polar identification

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own, carrying the planets with it. This conjecture has been strengthened by the observations of Argelander, Otto Struve, and Bravais. In 1834 the Rev. H. M. Grover, of Hitcham Rectory (an able mathematician), pointed out in his 'Theory of the Sun's Orbit,' that the sun's proper motion would adequately account for all the phenomena of precession; and the same idea has since been advanced by others.

* It is now doubted whether this effect should be described strictly as a *nutatio*, or "nodding" to and fro of the earth's axis. The apparent oscillation may not be in the axis, but in the ecliptic; and be occasioned by a spiral and epicyclar movement of the earth about the plane of its orbit.

† 'En. Brit.,' Art. Astronomy, by Thomas Galloway, F.R.S.

‡ It has been shown, conclusively, that this could hardly result from the elevations and subsidences of volcanic agency, the internal forces of which must be governed from the first by the diurnal motion; but a more potent cause of possible evagation exists in the unequal action of the sun's rays; the effect of which is a constant wasting of the earth's solids by their volatilization in some parts of the world, while other parts are receiving continual accretions by precipitation.

§ As stations in the Arctic seas are required for various objects, let me, here, offer a suggestion. Our colonies refuse to receive convicts. Russia sends hers to Siberia. Why not send ours north, likewise; where their labour could be utilised? The discovery of coal strata in the Parry Islands has removed the main difficulty; which has not been want of food, but want of fuel. The work of excavating coal, in underground galleries, could be as easily carried on in Arctic regions as at Newcastle. A few coaling stations, at intermediate points, to be used besides for depôts of provisions, and as places of refuge, may one day render a voyage to British Columbia, at the right season, *viâ* the Pole and Behring Strait, an every-day enterprise.

may be so performed (astronomical commissions of different nations taking part in it) that no future question may arise about the place of the Pole of our own day, and of its exact bearings, celestial and terrestrial. If there be no granite peaks in the neighbourhood by which its position could be geodetically defined, the leading states of Europe and America would confer an immense boon upon posterity by combining to erect there a monument as enduring as the pyramid of Gizeh, from which could be read in the changed aspects of the heavens the history of the earth's past and future: for it is principally from data to be obtained at the Pole that we have to expect an answer to the question geologists have long asked of astronomers, "What is the cause of those changes of climates we find recorded in the earth's crust?"

We know from fossil remains, the coal formations, and the cargoes of bones of *mammalia* freighted annually from Siberian seas, that there must once have been a time when animal and vegetable life abounded in Arctic regions; and the recent melting of ice found to have been the tomb of extinct mammoths, would seem to indicate that it is approaching again.

The probability of such a change turns principally upon the causes of that *displacement of the plane of the ecliptic* alluded to, which is slowly but progressively diminishing its angle of obliquity. Our highest mathematicians hold the uniformity of the earth's rotatory motion to involve a perfect parallelism of the earth's axis; but a change of plane in the earth's path affects the earth's solar aspects exactly in the same way as a change of direction in the earth's axis, with the plane of orbit remaining constant. The obliquity of the earth's path in reference to the plane of the equator (or, what is the same thing, the obliquity of the angle made by the Pole of the ecliptic and the Pole of the equator), as measured by Eratosthenes, 2000 years ago, was 23° 51′ 52″; it is now 23° 27′ 26″; at which rate of diminution the two planes would meet in about 100,000 years. The rate is now slower—about 45″ in a century; the causes commonly assigned for it (the perigee and apogee, or approach to and departure from the earth's path of other planets) accelerating the diminution at one time, and retarding, arresting, or counteracting it at another. Assuming the varying positions of Mars and Jupiter to be the principal cause of ecliptic displacement, M. le Verrier has calculated the change of obliquity to be confined within a range of 9° 44′; but no one has yet been put in possession of all the elements required for a solution of this problem. The value, for example, of the aggregate mass of the eighty-three planetoids recently discovered has to be determined; and, if we are to accept the doctrine that the sun has an orbit of its own, and that its present orbital path is in the direction of a star in the constellation Hercules, north and west of the plane of the ecliptic (shifting, therefore, more and more to the

north-west, in the orbit of every planet, the solar centre of gravitation), the dynamic consequences of such a movement have to be computed.

The Egyptian priests of antiquity had a tradition that the ecliptic was at one time at right angles with the plane of the equator; an idea to which they may have been led by the diminution of obliquity now in progress (observed, perhaps, in their day); for a ratio of decrease in the present is of course a ratio of increase for the past: and if, in looking backward, we have no rule where to stop, we must of course reach at last an angle of 90°; when the question arises whether the plane of all orbital paths may not *revolve* as well as oscillate. The varying inclination of the orbits of all the heavenly bodies, for which no cause has been assigned, is a reason for not considering a complete revolution of their planes impossible. While the plane of the path of Jupiter differs from that of the earth but 1° 18′ 40″, and Mercury but 1° 51′ 5″, Mars departs from it 7° 0′ 8″, and Pallas 34° 43′ 17″. The satellites of Uranus revolve in a plane perpendicular to that of their primary, and the comet of June, 1861, dropped down upon us from the circumpolar stars at an angle of 85° 58′.

As the change of seasons depends upon the obliquity of the ecliptic, and the extent of that change upon the degree of obliquity, the evidence offered by geology of the temperate regions of the globe having been subject to extreme alternations of heat and cold, supports the conclusion that our own orbital path must at some period have formed a much wider angle with the plane of the equator than at present. An angle of 90° represents (*cæteris paribus*) the maximum of possible alternation; an angle of 45° the mean of possible alternation; 23° 28′ the present alternation; which angle, reduced to *nil*, leads us to the minimum, or zero of possible change, in equable temperatures throughout the year.

An ecliptic at right angles with the plane of the equator would bring the sun at the North Pole at Midsummer into the zenith, where, remaining throughout the twenty-four hours, it would, by its continued action, produce an intensity of heat, over the whole Arctic circle, far greater than that now experienced in the Torrid Zone. After the autumnal equinox, the gradual cooling of the atmosphere, and condensation of aqueous vapours the sun had exhaled, would occasion deluging rains, and then overwhelming falls of snow; followed, on the approach of the winter solstice, (when the sun would sink 90° below the horizon), by a glacial epoch, that would lock up in ice at least one-third of the northern hemisphere. These changes, powerfully influencing all atmospheric and ocean currents, would necessarily be accompanied by storms, and convulsions of great violence.

A progressive diminution of obliquity is a tendency towards

quite an opposite state of things,—one of a universal calm, free from physical disturbances of any kind. A near approach of the two planes would bring about, as in the planet Jupiter,* equal days and nights all over the world, throughout the year, with equal temperatures; the latter varying only with latitude. From the equator to the British Isles there would reign perpetual summer, and, farther north, perpetual spring. Winter, in its severer forms, would be banished from the globe (the sun at the Poles being always on the horizon); and the only winds that would prevail would be trade winds, blowing constantly from the same quarter.

It becomes, of course, no student of science to dwell upon such eventualities, further than as a tentative process for the discovery and understanding of facts. The point for his attention is that we want far more information than we possess of the causes that govern the present inclination alike of the earth's orbit and that of the earth's axis, both of which (however strong the presumption against change of axis), may have a concurrent variation; and that the business-like way to obtain the data we desire is to establish astronomical and geodetic stations at such extreme points of the earth's circumference as would settle the question of the earth's figure, and of its exact angular position in all apparent perturbations of the heavenly bodies.

XI.—*On the Bayanos River, Isthmus of Panama.* By LAURENCE OLIPHANT, Esq., Secretary R.G.S.

Read, April 24, 1865.

THE practicability of uniting the Atlantic and Pacific Oceans by means of a ship-canal has long occupied the attention not only of geographers, but of men of science and of commerce. It is not my intention now to recapitulate the various schemes which have been set on foot to accomplish so desirable an object, or to enter upon a narrative of the different expeditions which have been fitted out at great trouble and expense to explore impossible routes, and to return with the same tale of failure, and sometimes of disaster; suffice it to say that, from one cause or other, no less than seven projects have fallen to the ground, and the public seems to have abandoned in despair the idea of achieving a work of such incalculable benefit to the world at large. It may be that they are right, and that the enterprise will in point of fact turn out not to be feasible; but this is a conclusion which no one has any right

* The obliquity of Jupiter is but 3° 6'; this, however, arises not from any divergence of its orbital path, which is nearly on the same plane as that of the earth, but from the greater perpendicularity of its axis.